"g-2+J-PARC(general+KOTO)"

with an overview of Particle and Nuclear Physics at IPNS

P5 townhall meeting at Fermilab

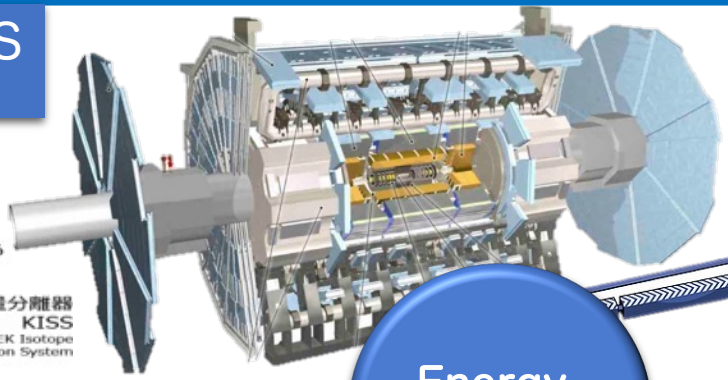
March 21-22, 2023

Naohito SAITO

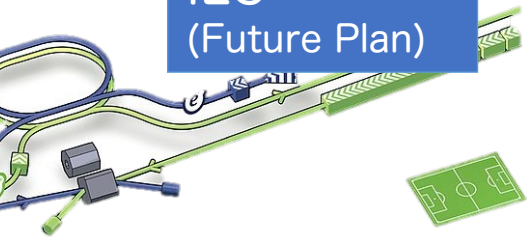

KEK
IPNS
Institute of Particle and Nuclear Studies
IMSS
Institute of Materials Structure Science
QUP
International Center for Quantum Field Measurement Systems for Studies of Particle and Universe
ACCL
Accelerator Laboratory
ARL
Applied Research Laboratory
J-PARC
Japan Proton Accelerator Research Complex
大強度陽子加速器施設
J-PARC
Tsukuba Campus
Tokai Campus

KISS
(at RIKEN)

ATLAS
(CERN)



ILC
(Future Plan)

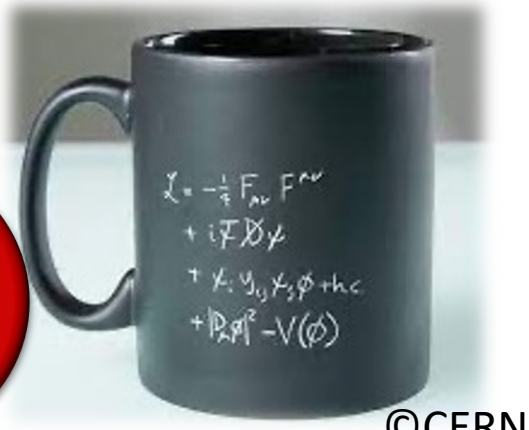


Energy
Frontier

Hadron Exp. Facility
(J-PARC)

Hadron
Nuclear

Theory



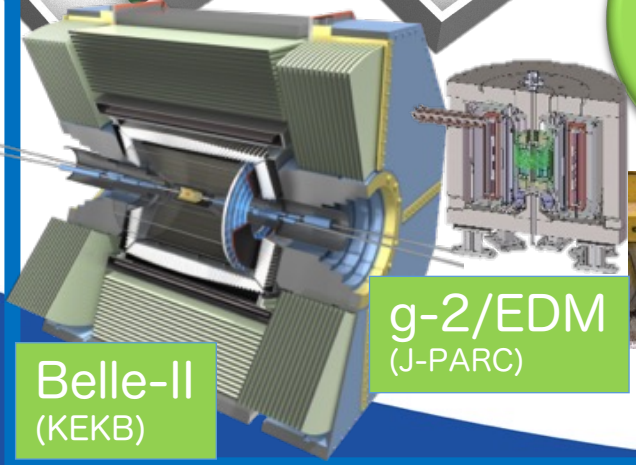
KOTO exp
(J-PARC)

COMET
(J-PARC)

Flavor
Physics

Astro-
Particle

LiteBIRD
(Space)



g-2/EDM
(J-PARC)

Belle-II
(KEKB)

UCN
(TRIUMF)

T2K and Hyper-K
(J-PARC& Kamioka)

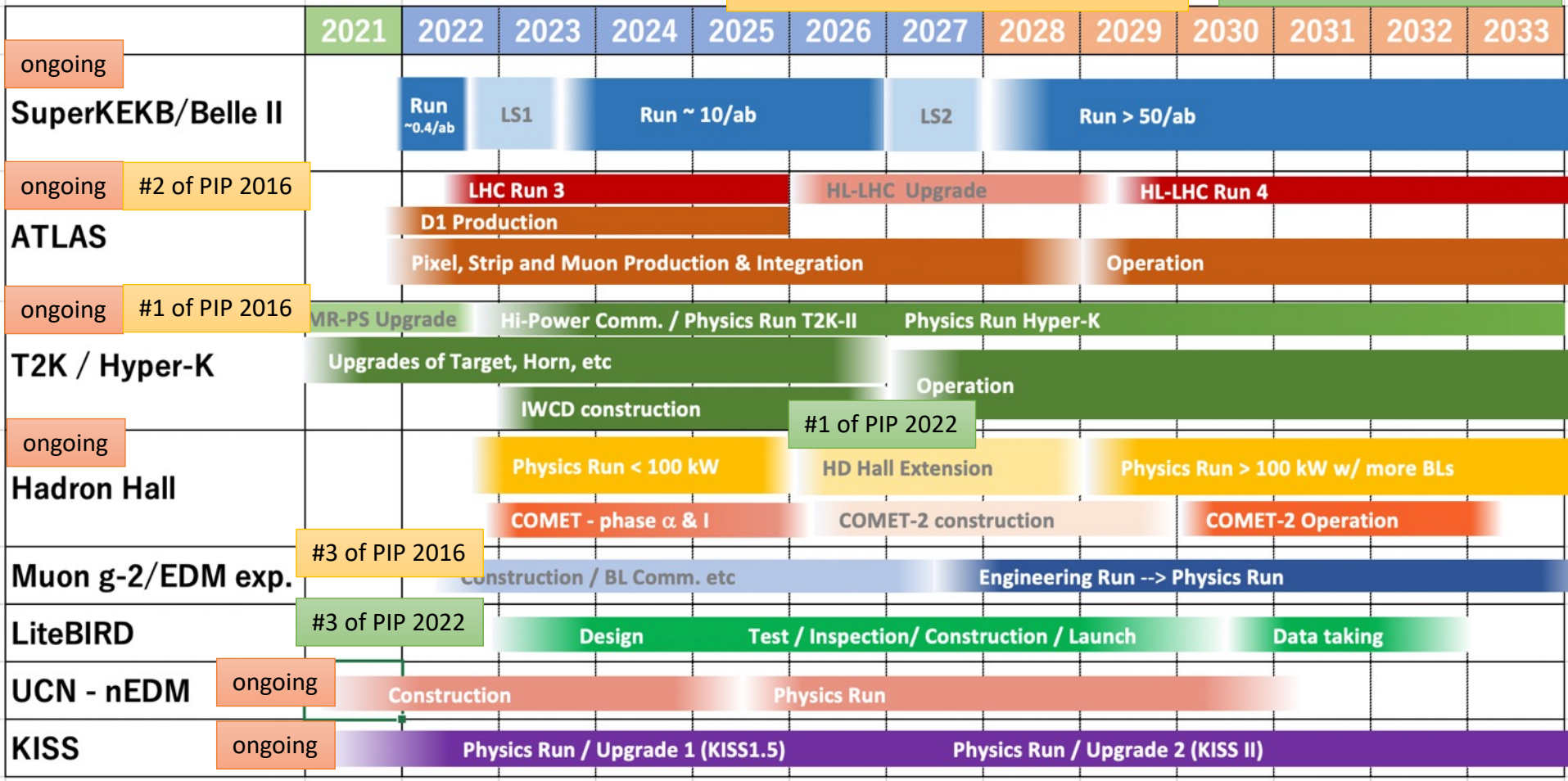
The Timeline (ver 2023.03.22)

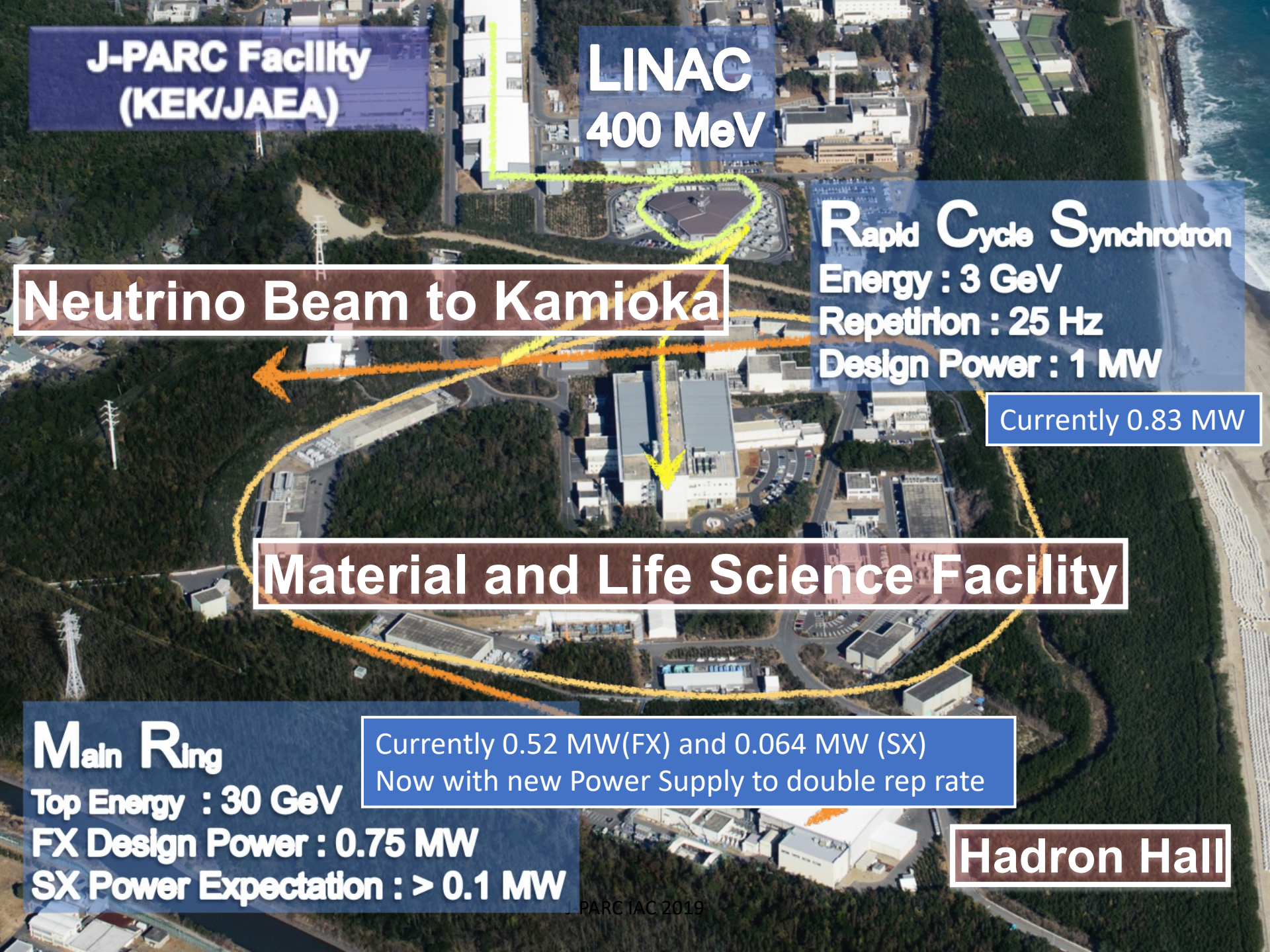
subject to change

- Intended schedule by IPNS.
- Decadal plans for SuperKEKB and J-PARC are approved by MEXT.
- HL-LHC is to be reviewed soon.

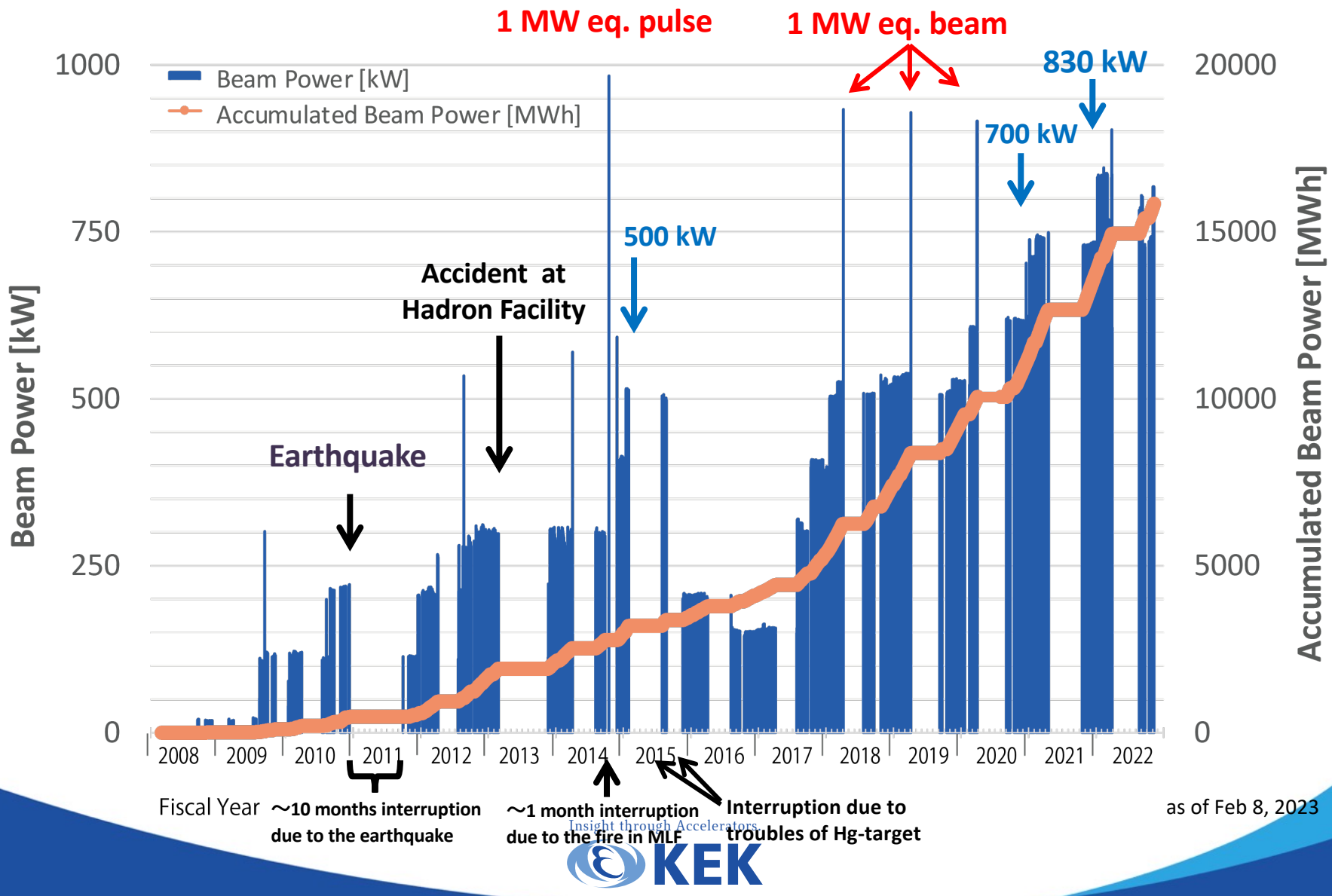
PIP2016
1. Hyper-K /J-PARC upgrades
2. HL-LHC
3. muon g-2/EDM
4. HEF extension

PIP2022
1. HEF extension
2. HL-LHC++
3. LiteBIRD
4. Muon Microscope

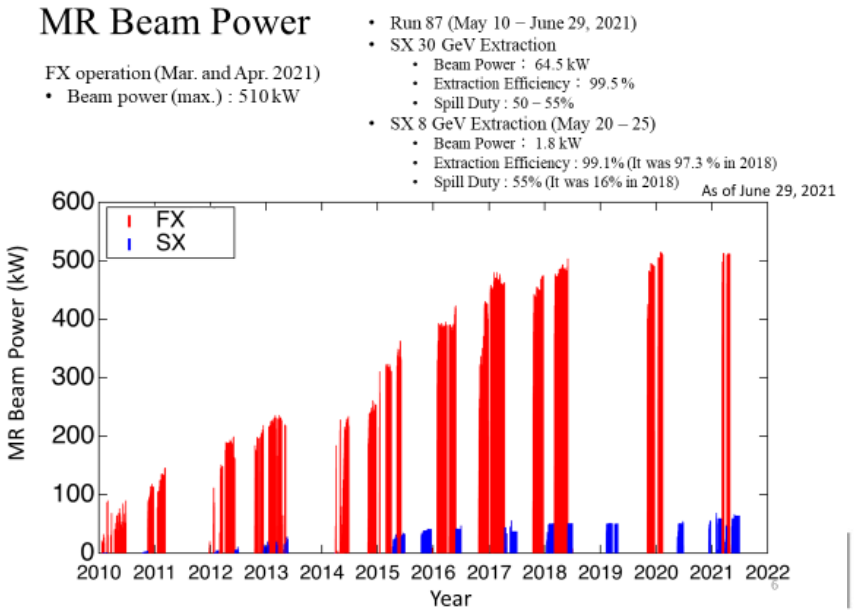



J-PARC Facility
(KEK/JAEA)
LINAC
400 MeV
Rapid Cycle Synchrotron
Energy : 3 GeV
Repetirion : 25 Hz
Design Power : 1 MW
Currently 0.83 MW
Neutrino Beam to Kamioka
Material and Life Science Facility
Main Ring
Top Energy : 30 GeV
FX Design Power : 0.75 MW
SX Power Expectation : > 0.1 MW
Currently 0.52 MW(FX) and 0.064 MW (SX)
Now with new Power Supply to double rep rate
Hadron Hall

Beam Power History at MLF



30GeV Main Ring status



- Achieved stable operation at
  - FX:515kW
  - SX: 64kW

  Before major upgrade
- Major upgrade for power up
  - Rep rate 2.48s → 1.32s (→ 1.16s)
  - Ppp 260Tp → 330Tp
  - L.S. from Summer 2021~ March 2022 for installation
- ~2022/3 New PS installation
- 2022/4~ PS test operation/tunning
- 6/27-7/7 : Beam circulated @ 3GeV
- After some unexpected initial failure, beam operation restarted Jan 23, 2023!

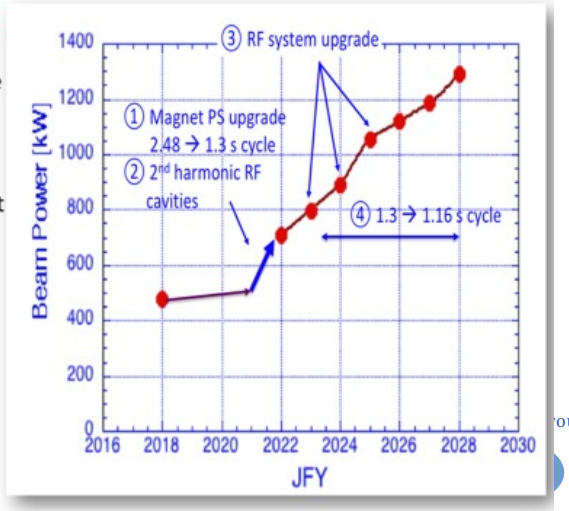
More Rapid Cycle:

2.48 s → 1.32 s → 1.16 s

- Main Power Supply to be renewed
- High gradient RF Cavity
- Improve Collimator
- Rapid cycle pulse magnet for injection/extraction

More Protons / Pulse :

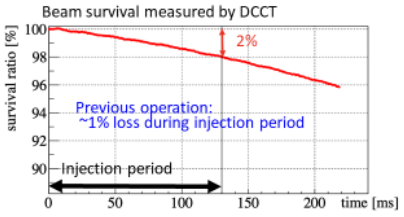
- Improve RF Power
- More RF Systems
- Stabilize the beam with feedback

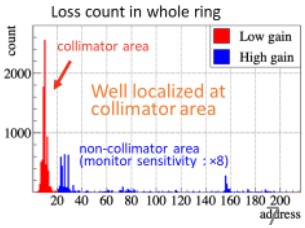


High Intensity Beam Tuning

- High-intensity beam study was performed with two bunch beams (2.7×10^{13} ppb) at the flat-bottom.
- Although the beam loss during the injection period was a little worse, loss localization was very good.

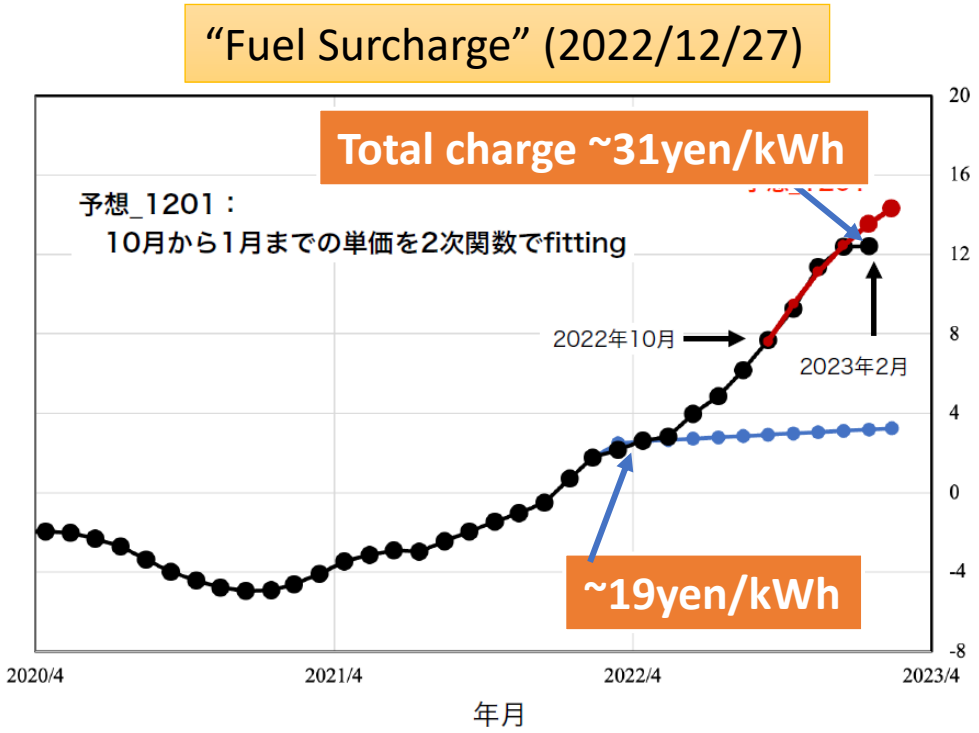
→ Protons of 740 kW equivalent were accumulated with well-controlled beam loss.





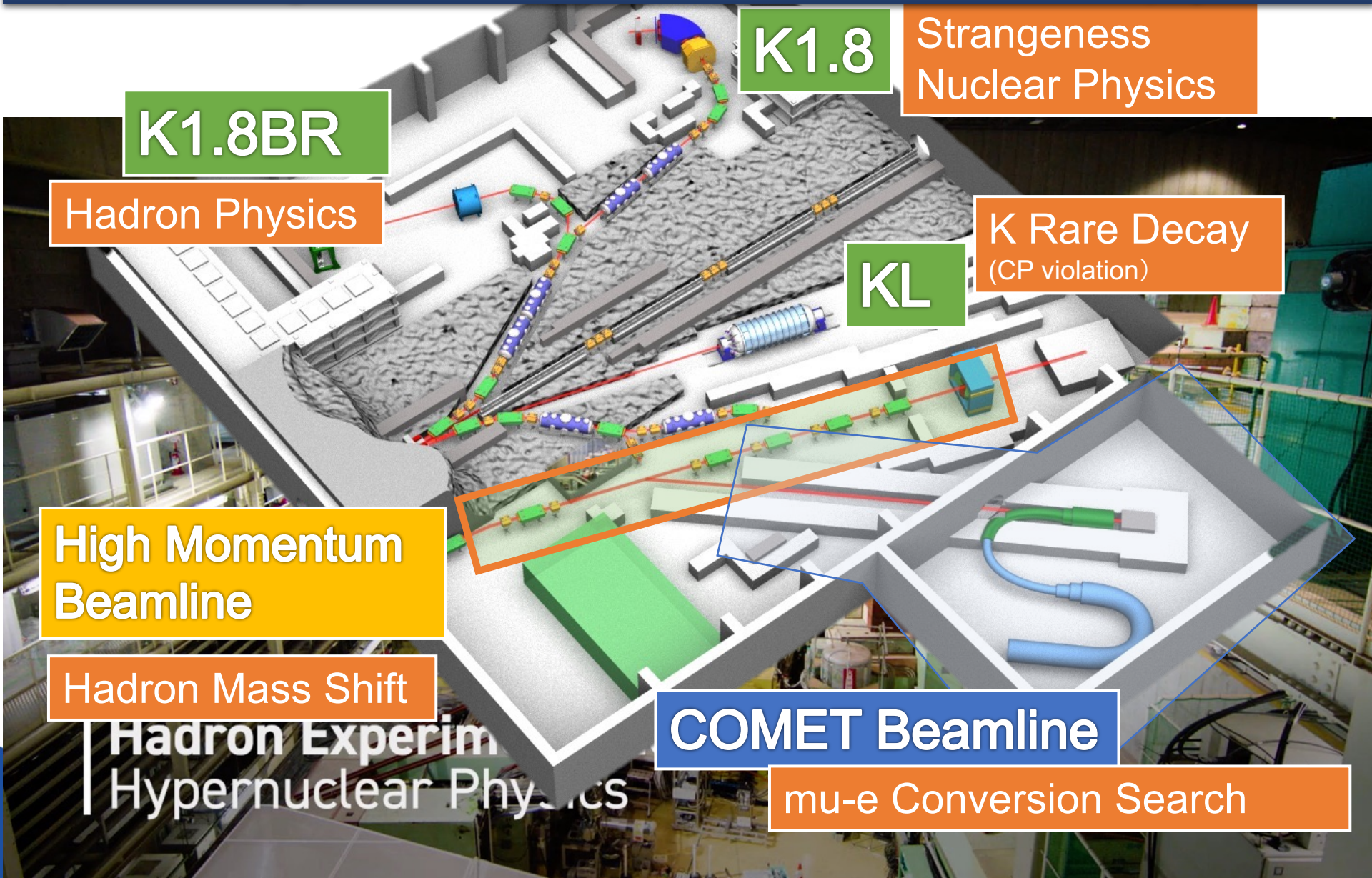
Electricity in FY2022 and further

- Unit price kept rising up during whole FY2022 exceeding our assumption of rise
  - JAEA announced in July to run until Feb. 10
  - KEK anticipated operation until around early March
- Nov. 2023: Supplementary budget for electricity for both JAEA and KEK
  - LI/RCS/MLF operation extended until Mar. 14
  - KEK also ran until Mar.14



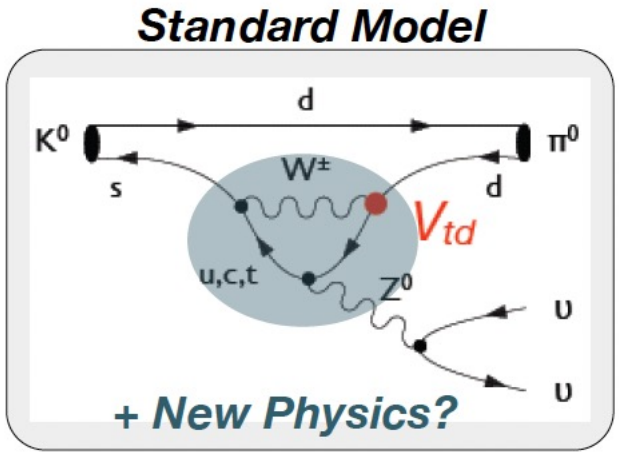
Hadron Experimental Facility

Explore the origin of matter with nuclear, hadron, and flavor physics

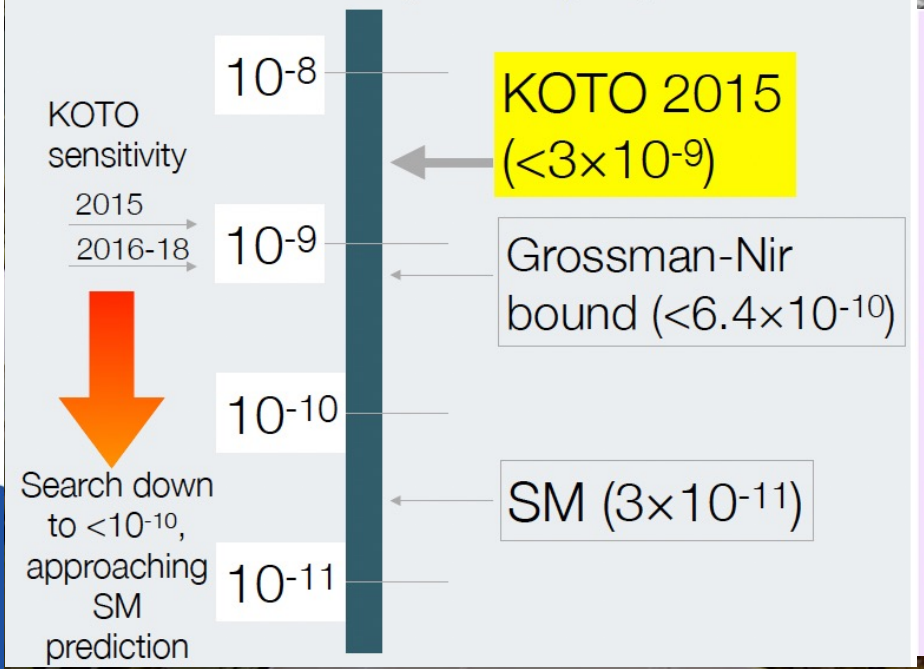


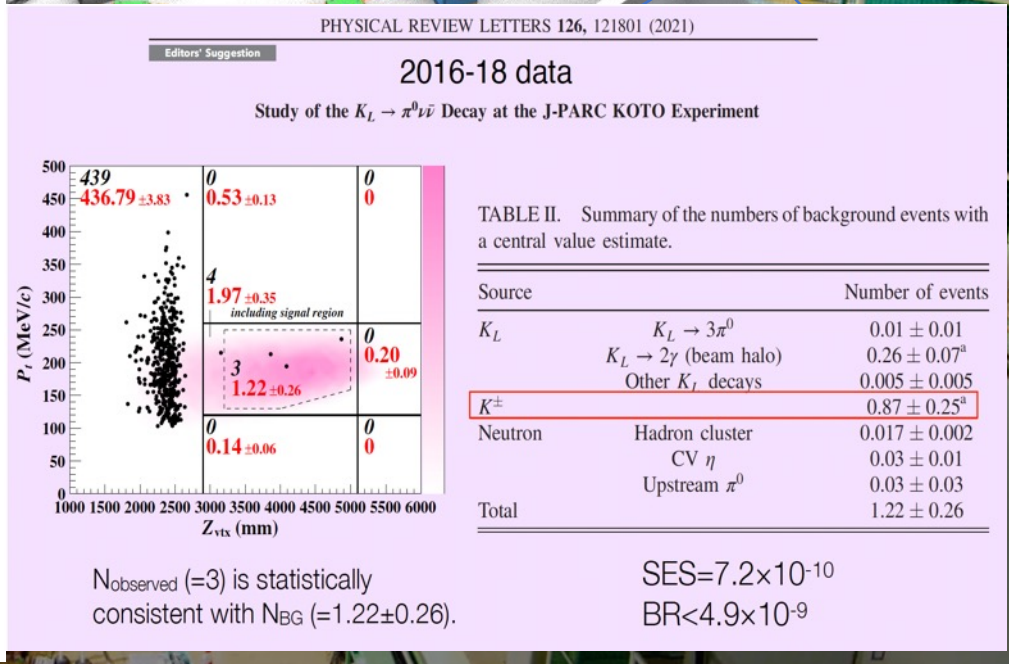
KOTO

Search for direct CPV in KL d



Branching ratio (BR)





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Editors' Suggestion

2016-18 data

Study of the $K_L \to \pi^0\nu\bar{\nu}$ Decay at the J-PARC KOTO Experiment

TABLE II. Summary of the numbers of background events with a central value estimate.

Source		Number of events
K_L	$K_L \to 3\pi^0$	0.01 ± 0.01
	$K_L \to 2\gamma$ (beam halo)	0.26 ± 0.07^a
	Other K_L decays	0.005 ± 0.005
$K^\pm$		0.87 ± 0.25^a
Neutron	Hadron cluster	0.017 ± 0.002
	CV η	0.03 ± 0.01
	Upstream π^0	0.03 ± 0.03
Total		1.22 ± 0.26

$N_{observed}$ (=3) is statistically consistent with N_{BG} (=1.22±0.26).

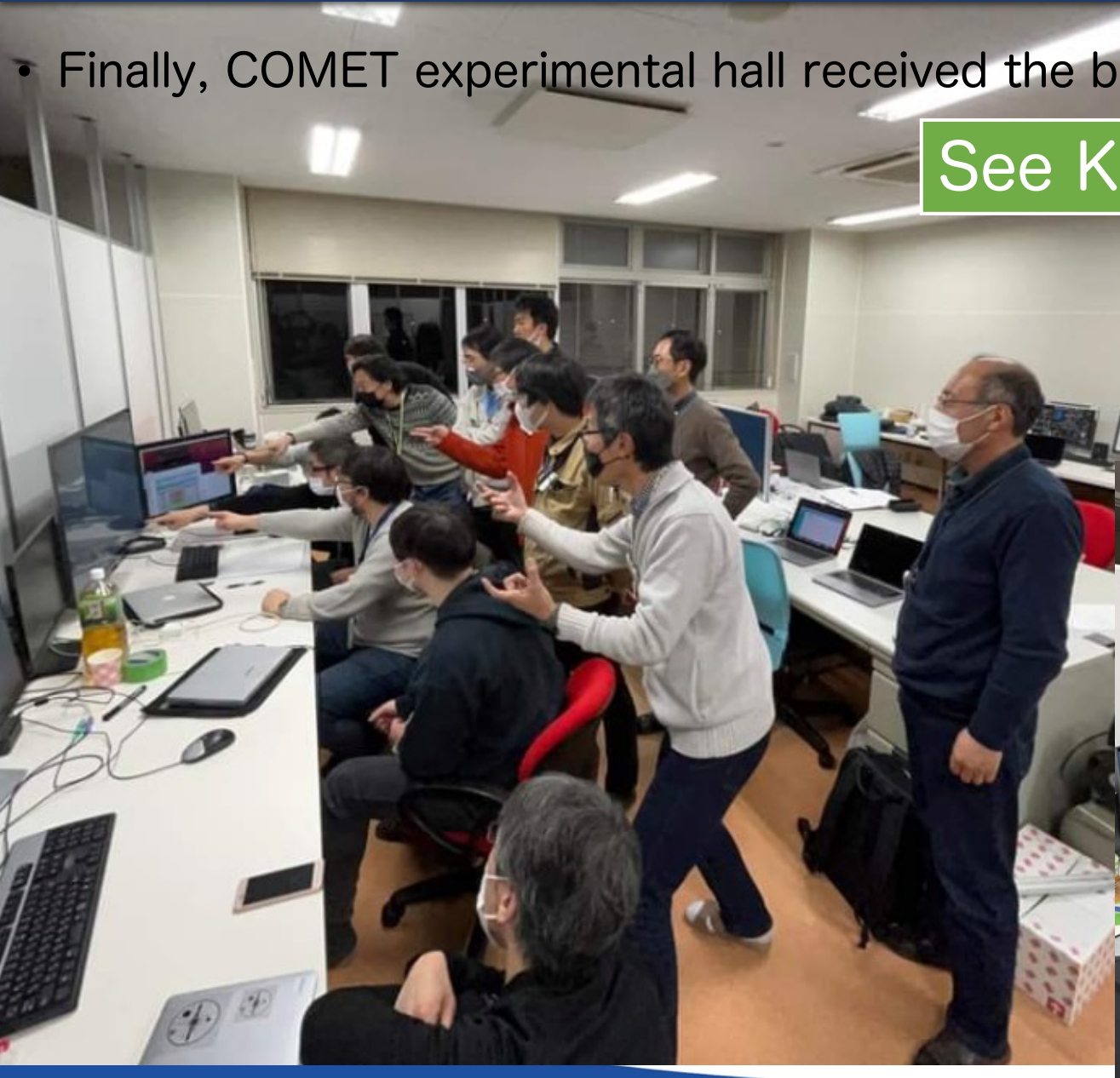
SES=7.2×10-10

BR<4.9×10-9

COMET Phase-α excitements

- Finally, COMET experimental hall received the beam!

See Kuno-san's talk!

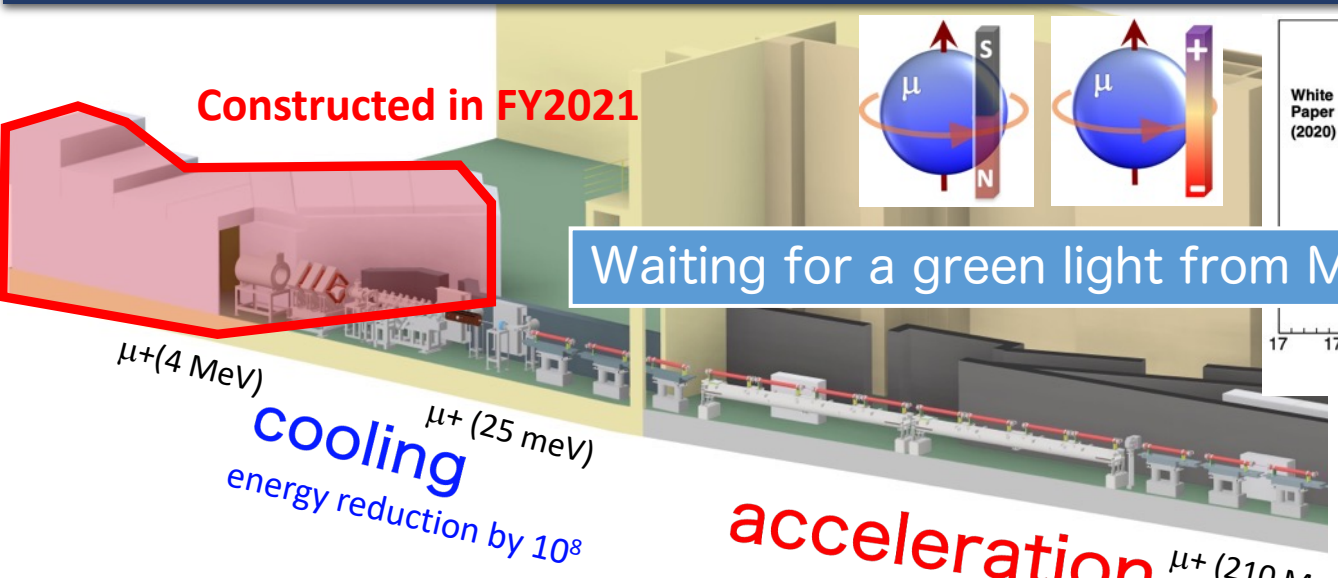



Muon g-2/EDM at J-PARC

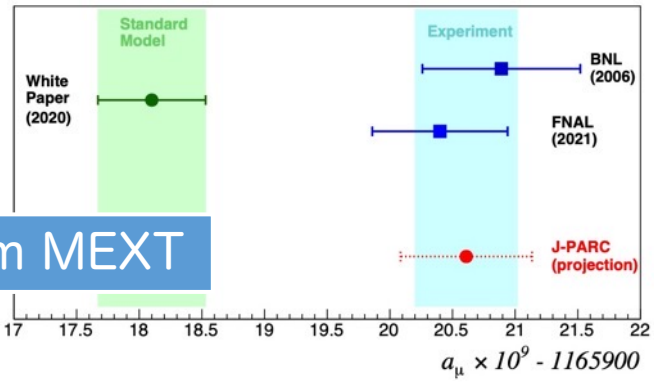
Material and Life science Facility

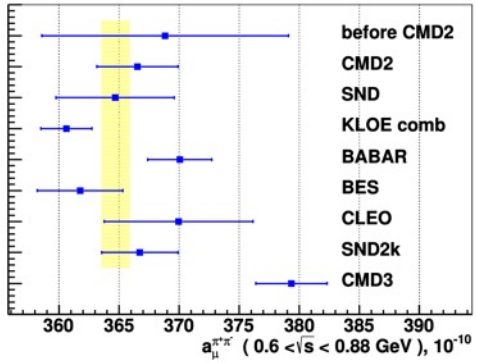
Muon g-2/EDM Experiment

Precision measurements of lepton moments with novel technique



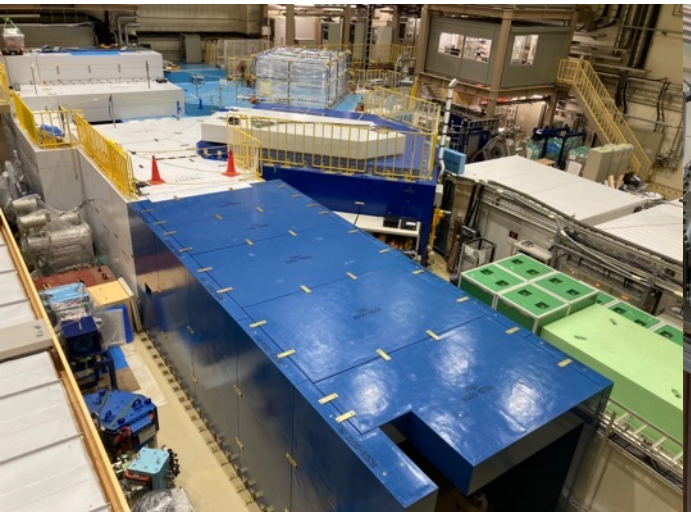
Waiting for a green light from MEXT





Construction in progress

Radiation shields



Muon cooling + LINAC

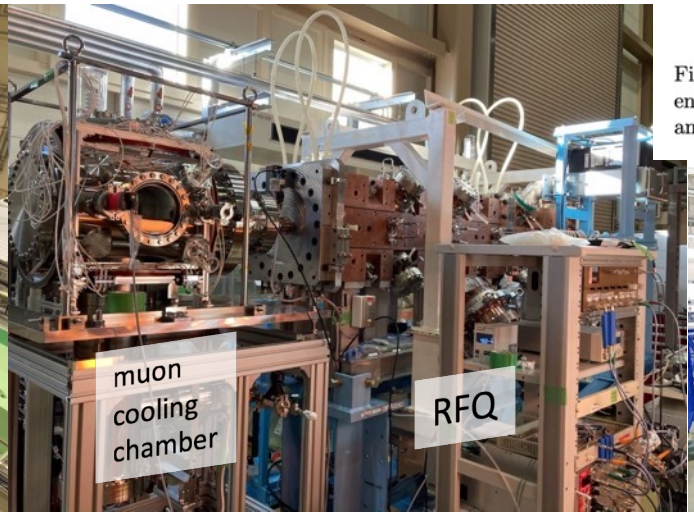
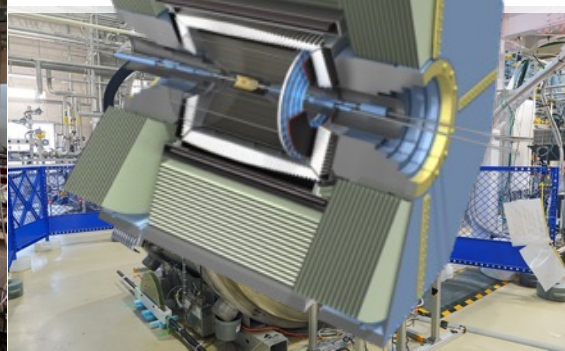
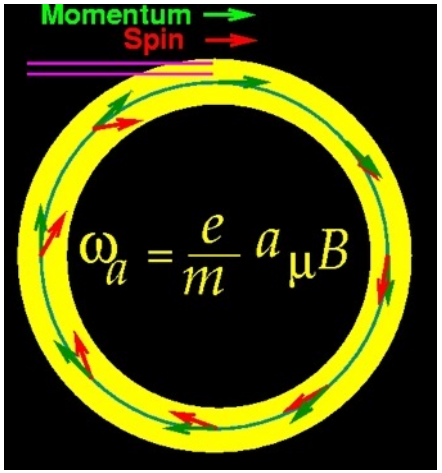


Figure 36: T… …ed LO from energy ra… …this and other …



Spin precession of muon

In uniform magnetic field, muon spin rotates ahead of momentum due to g-2 ≠ 0



Spin precession vector w.r.t momentum :

$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} - \left(a_\mu - \frac{1}{\gamma^2 - 1}\right)\frac{\vec{\beta}\times\vec{E}}{c} + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B} + \frac{\vec{E}}{c}\right)\right]$$

g-2 precession in B-field

g-2 precession in motional B-field

EDM precession

BNL/FNAL approach
γ=30 (P=3 GeV/c)

J-PARC approach
E = 0 at any γ

$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B} + \frac{\vec{E}}{c}\right)\right]$$

$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B}\right)\right]$$

BNL & FNAL E989

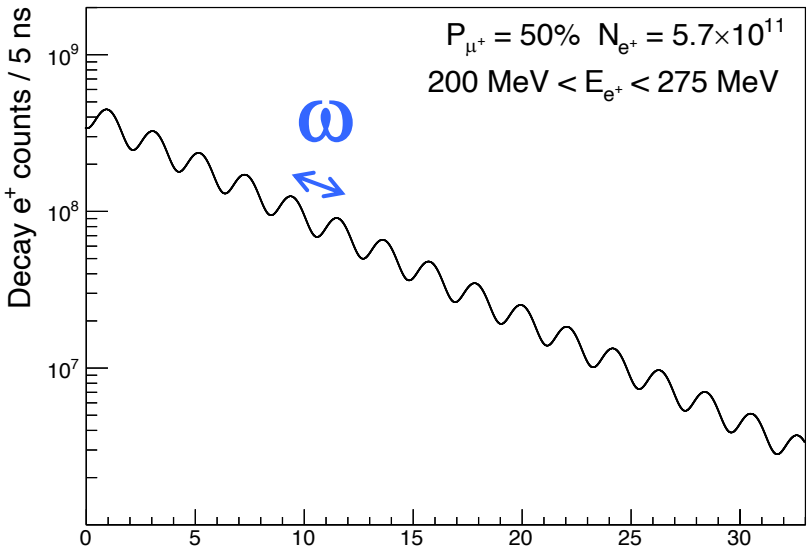
J-PARC E34

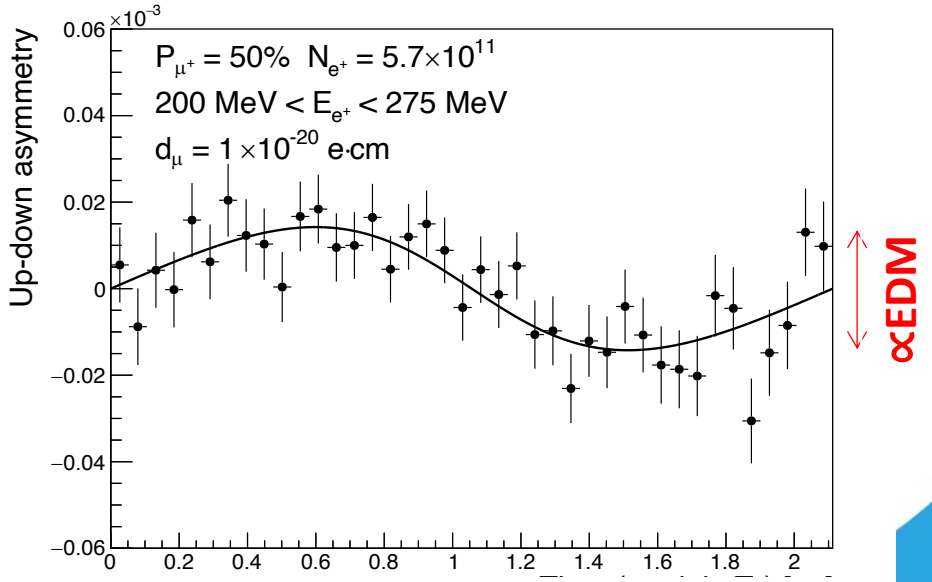
Insight through Accelerators.
KEK

Simultaneous measurements: g-2, EDM

$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} + \frac{\eta}{2}\left(\vec{\beta} \times \vec{B}\right)\right]$$

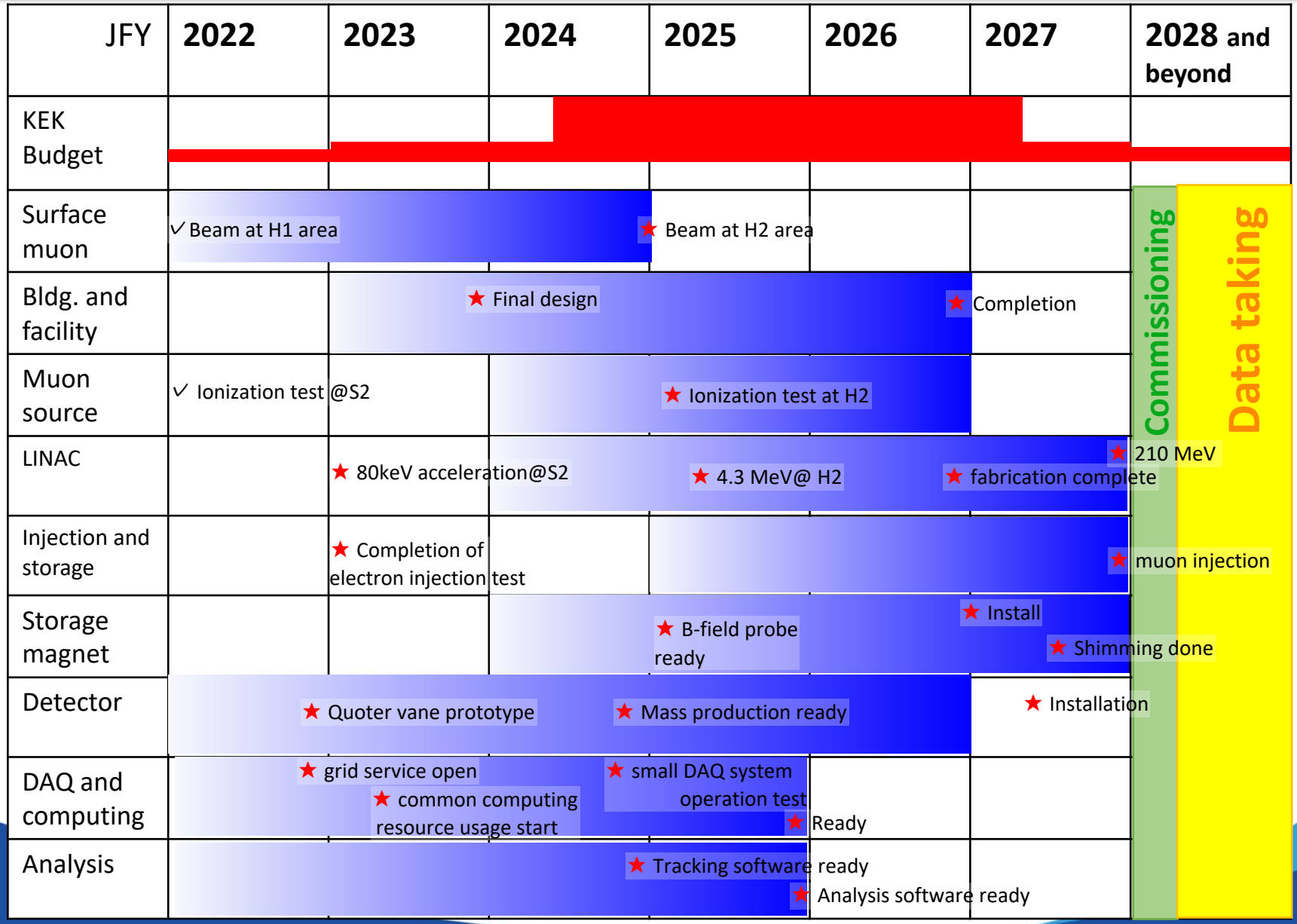
Expected time spectrum of e^+ in $\mu \rightarrow e^+\nu\nu$ decay





Revised schedule and milestone

PAC35 (Jan. 2023)



Summary

- J-PARC covers important sector of Flavor Physics!
  - T2K-II waits for new MR beam / Hyper-K project proceeding as scheduled so far.
  - New results coming out for nuclear-hadron physics at HEF
    - COMET finally started to receive the beam!
    - KOTO is making solid progress.
  - MLF experiments
    - sterile neutrino search JSNS^2 continues; the 2nd detector
    - Muon g-2/EDM is under construction waiting for a “real green light” from MEXT

Let's Share More Excitements!